

What is claimed is:

1. A method of forming a three-dimensional (3D) photonic crystal waveguide structure, comprising:
  - 5 forming in first and second substrates respective first and second 3D photonic crystal regions respectively comprising first and second substantially identical periodic arrays of voids defining substantially identical first and second complete bandgaps;
  - 10 forming a first channel in the first 3D photonic crystal region; and
  - 15 interfacing the first and second 3D photonic crystal regions to form a 3D waveguide defined by the first channel and a portion of the second 3D photonic crystal region covering the first channel.
2. The method of claim 1, wherein the method includes forming the first and second periodic arrays of voids via surface transformation.
3. The method of claim 1, wherein the method includes:
  - 15 determining a filling ratio of voids needed to produce the first and second complete bandgaps; and
  - 20 forming voids in the first and second substrates to achieve the determined filling ratio.
4. The method of claim 3, wherein the method includes forming the first and second periodic array of voids from unit cells connected by imaginary bonds, and
  - 25 forming second voids along the imaginary bonds.
5. The method of claim 4, wherein the method includes forming the first and second voids as spherical voids.

6. The method of claim 1, wherein the method includes forming a second channel in the second 3D photonic crystal region, and aligning the first channel with the second channel when interfacing the first and second 3D photonic crystals so that the 3D waveguide is defined by the first and second channels.

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7. The method of claim 1, wherein the method includes forming the first channel to have a rectangular cross-section.

8. A method of forming a 3D photonic crystal waveguide structure, comprising:  
10 combining two 3D photonic crystal regions each formed from a substantially identical periodic array of voids via surface transformation so as to form a complete bandgap in each 3D photonic crystal region; and  
wherein at least one of the 3D photonic crystal regions includes a channel that forms a waveguide upon said combining of the two 3D photonic crystal regions.

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9. The method of claim 8, wherein the method includes forming the voids to be spherical voids.

10. The method of claim 9, wherein the method includes arranging the periodic arrays of voids to form a modified diamond crystal structure.  
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11. The method of claim 8, wherein the method includes forming the channel to include a taper.

25 12. The method of claim 8, wherein the method includes forming the channel to include a bend.

13 The method of claim 8, wherein the method includes forming the periodic array of spherical voids from unit cells, and forming the channel be at least one unit cell in width and at least one unit cell in depth.  
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14. The method of claim 8, wherein the method includes forming the channel by etching at least one of the two 3D photonic crystal regions.

15. The method of claim 8, wherein combining the two 3D photonic crystal regions 5 includes aligning alignment marks formed relative to each of the two 3D photonic crystal regions.

16. A method of guiding radiation, comprising:  
forming in first and second substrates respective first and second 3D photonic  
10 crystal regions respectively including first and second substantially identical periodic  
arrays of voids defining substantially identical first and second complete bandgaps;  
forming a first channel in the first 3D photonic crystal region;  
interfacing the first and second 3D photonic crystal regions to form a 3D  
waveguide defined by the first channel and a portion of the second 3D photonic crystal  
15 region covering the first channel; and  
introducing radiation into an input end of the 3D waveguide.

17. The method of claim 16, wherein the method further includes detecting  
radiation at an output end of the 3D waveguide and generating an electronic signal in  
20 response thereto.

18. The method of claim 16, wherein the method further includes processing the  
electronic signal.  
25 19. The method of claim 16, wherein the method includes forming the first and  
second periodic arrays of void by surface transformation.

20. A method of guiding radiation, comprising:  
combining two 3D photonic crystal regions having formed therein substantially identical periodic arrays of voids via surface transformation so as to form a complete bandgap in each 3D photonic crystal region, wherein at least one of the 3D photonic  
5 crystal regions includes a channel that forms a waveguide upon said combining of the two 3D photonic crystal regions; and  
introducing radiation into the waveguide having a wavelength within the complete photonic bandgap.
- 10 21. The method of claim 20, wherein the method includes forming the voids to be spherical.
22. The method of claim 20, wherein the method includes forming the two 3D photonic crystal regions to each comprise a modified diamond crystal structure.
- 15 23. A method of forming a 3D photonic crystal waveguide, comprising:  
forming first and second substantially identical 3D photonic crystal regions, wherein at least one of the regions includes a channel; and  
combining the first and second 3D photonic crystal regions to form a single 3D  
20 photonic crystal region with a waveguide defined by the channel, the single 3D photonic crystal having a complete photonic bandgap defined by first and second periodic arrays of voids formed in each of the first and second 3D photonic crystal regions.
- 25 24. The method of claim 23, wherein the method includes forming the first and second periodic arrays of voids by surface transformation.
25. The method of claim 23, wherein the method includes forming the voids as spherical voids.

26. The method of claim 23, including forming the first and second 3D photonic crystal regions with unit cells of first spherical voids having a diamond structure modified with second spherical voids to form the complete bandgap.

5 27. The method of claim 23, wherein the method includes:  
selecting a desired wavelength for the complete photonic bandgap; and  
forming the periodic array of voids to have a period a fraction of the desired wavelength.

10 28. The method of claim 27, wherein the desired wavelength is one of x-ray, ultraviolet, visible, infrared, and microwave.

29. The method of claim 23, wherein the first and second 3D photonic crystal regions are formed in respective first and second substrates, and wherein combining the 15 first and second 3D photonic crystal regions includes interfacing and bonding the substrates.

30. A waveguide structure comprising:  
first and second 3D photonic crystal regions combined to form a single 3D 20 photonic crystal region having a complete photonic bandgap defined by first and second periodic arrays of voids formed in each of the first and second 3D photonic crystal regions by surface transformation; and  
a channel passing through the single 3D photonic crystal region sized to receive and guide radiation of a wavelength corresponding to the complete photonic bandgap.

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31. The waveguide structure of claim 30, wherein the voids are spherical.

32. The waveguide structure of claim 30, wherein the first and second periodic arrays of voids form a modified diamond crystal structure.

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33. The waveguide structure of claim 30, wherein the channel includes a bend.

34. The waveguide structure of claim 30, wherein the channel includes a taper.

5 35. A waveguide structure, comprising:

a 3D photonic crystal including a periodic array of voids formed in a solid substrate so as to have a complete photonic bandgap; and

a channel waveguide formed in the 3D photonic crystal and sized to transmit light of a wavelength corresponding to the complete photonic bandgap.

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36. The waveguide structure of claim 35, wherein the 3D photonic crystal includes first and second interfaced 3D photonic crystal regions formed in first and second substrates.

15 37. The waveguide structure of claim 35, wherein the voids are spherical.

38. The waveguide structure of claim 35, wherein the periodic array of voids includes a plurality of cells having a modified diamond structure.

20 39. The waveguide structure of claim 35, wherein the channel waveguide has a bend.

40. The waveguide structure of claim 35, wherein the channel waveguide has a rectangular cross-section.

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41. The waveguide structure of claim 35, wherein the channel waveguide includes a taper.

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42. The waveguide structure of claim 35, wherein the substrate includes a material selected from the group of materials consisting of a linear optical material, a non-linear optical material, a metal, a semiconductor, an insulator, a dielectric, an acoustic material, a magnetic material, a ferroelectric material, a piezoelectric material, and a 5 superconducting material.

43. The waveguide structure of claim 35, wherein the complete photonic bandgap has a wavelength including one of an x-ray wavelength, an ultraviolet wavelength, a visible wavelength, an infrared wavelength and a microwave wavelength.

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44. A waveguide optical system comprising:  
a 3D photonic crystal comprising a periodic array of voids formed in a solid substrate so as to have a complete photonic bandgap;  
a channel waveguide formed in the 3D photonic crystal and sized to transmit 15 light of a wavelength corresponding to the complete photonic bandgap; and  
a radiation source operatively coupled to a first end of the channel waveguide to provide radiation to be transmitted down the waveguide.

45. The waveguide optical system of claim 44, wherein the radiation source is a 20 laser.

46. The waveguide optical system of claim 44, further including a photodetector operatively coupled to a second end of the channel waveguide to detect radiation transmitted down the channel waveguide and generate an electrical signal in response 25 thereto.

47. The waveguide optical system of claim 44, further including an electronic system connected to the photodetector operable to receive and process the electronic signal.

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48. The waveguide optical system of claim 44, wherein the periodic array of voids is made up of unit cells, and wherein the unit cell is has been modified to form the complete photonic bandgap.

5 49. The waveguide optical system of claim 48, wherein the modified unit cells are modified diamond unit cells.